Restoratively Driven Implant Dentistry Utilizing Advanced Software and CBCT

Realistic Abutments and Virtual Teeth

Scott D. Ganz, DMD

During the past 20 years, advances in diagnosis and treatment planning software applications have evolved with the concomitant acceptance of computed tomography (CT) and cone beam CT (CBCT) technology. CBCT has been widely utilized to understand and appreciate patient anatomy since its introduction and adoption. The use of native, prepackaged software can serve as an excellent aid to evaluate potential implant receptor sites or assess bone grafting procedures. However, it is the synergy between CBCT data and advanced interactive planning software that fully empowers clinicians with the tools to achieve *true, restoratively driven implant dentistry*.

It is the synergy between CBCT data and advanced interactive planning software that fully empowers clinicians with the tools to achieve true, restoratively driven implant dentistry.

These concepts are not new. In an article by Cheryl Farr, which appeared in *Dentistry Today* (June 1995), the author discussed many of the same principles based upon the technology that existed at that time. This article will address the current state of the art in diagnosis, treatment planning, and CT-derived surgical guidance. Through the presentation of a partially edentulous case, for a single missing maxillary lateral incisor the author will illustrate concepts that can also be effective with multiple implants for partial or fully edentulous presentations. Additionally, the use of this technology affords clinicians with a powerful means of communication with all members of the implant team and an effective marketing tool to patients.

Figure 1a. Retracted frontal view revealing the congenitally missing lateral incisor.

Figure 1b. Close-up view illustrates the lack of interdental papilla, facial concavity, and the intertooth distance.

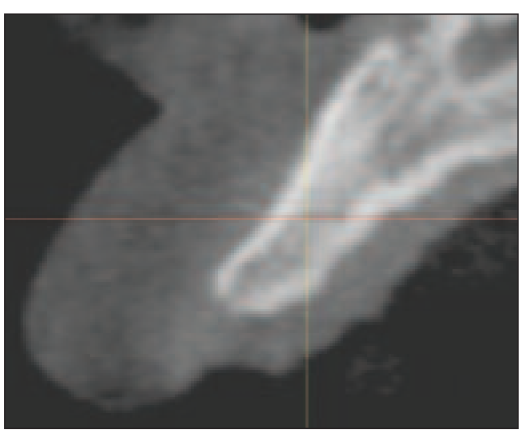

Figure 2a. The cross-sectional CBCT scan image aids in determining the available bone volume and density for the potential receptor site.

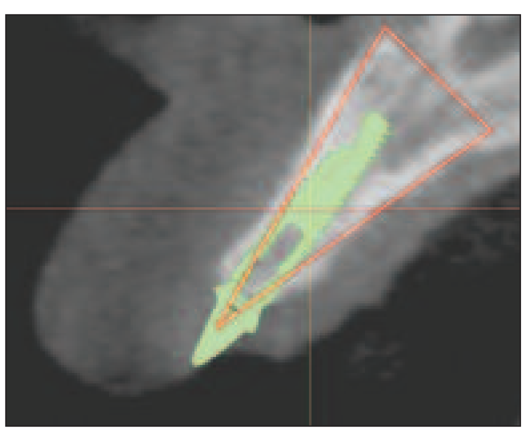

Figure 2b. A realistic implant and realistic abutment placed within the zone of the TOB.

CASE STUDY

A 33-year-old female presented with a congenitally missing maxillary right lateral incisor. Her medical history was unremarkable. The retracted, frontal view reveals the centric relation position (Figure 1a). The limited interarch space can be appreciated. The side view reveals the soft-tissue considerations, the lack of interdental papilla, the facial concavity, and the intertooth distance (Figure 1b). Her orthodontist had done well maintaining the space, and the patient had been wearing an appliance for approximately one year. The patient had been to several clinicians to determine the options to replace her missing tooth. Two-dimensional periapical radiographs revealed an adequate mesial-distal distance at the crest of the ridge for implant placement. However, the apex of the right central incisor was slightly convergent and appeared to be encroaching on the available space. Of particular interest was the disk the patient presented for consultation containing data from a CBCT scan, previously obtained from an i-CAT machine (Imaging Sciences International).

The CT scan data and use within the proprietary software (i-CAT Vision software) was helpful in visualizing the potential implant receptor site. However, to enhance the diagnostic information, the data was imported using SimPlant (Version 11 [Materialise Dental]), an interactive treatment planning software program with ad-

continued on page 124

Restoratively Driven Implant...

continued from page 122

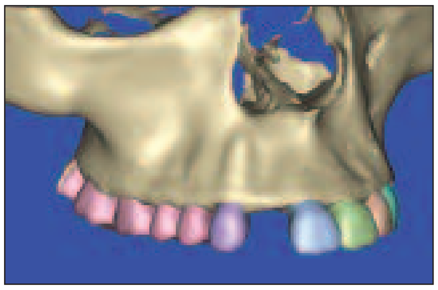

Figure 3a. The virtual 3-D model of the patient's maxilla revealing the contours of the bone and position of the adjacent teeth.

Figure 3b. Translucency provides an invaluable diagnostic aid by helping to visualize the underlying surrounding tooth roots.

Figure 4. The occlusal view of the maxilla showing the edentulous receptor site and the individually colored maxillary teeth.

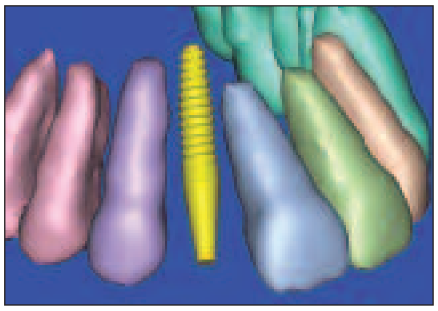

Figure 5a. A virtual realistic tapered implant chosen from the manufacturers' virtual library.

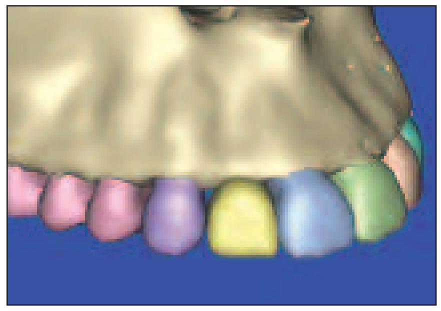

Figure 5b. The simulated virtual lateral incisor tooth aids in placing the implant properly.

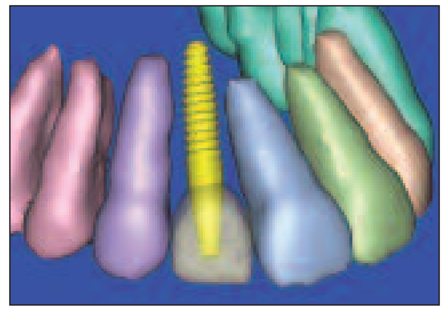

Figure 5c. Removing the bone and adding translucency helps to finalize the position of the implant and abutment.

vanced features. For a missing lateral incisor, it is important to consider the available bone volume, the bone quality, and the proximity of the adjacent tooth roots. The cross-sectional views will aid in determining the available bone volume and the bone density (Figure 2a).

In order to connect the implant location to the desired tooth restoration, it is useful to have a radiopaque scanning appliance worn at the time that the scan is taken. Unfortunately and as previously stated, the scan was taken before the patient was seen for consultation. Therefore, the ability to connect the implant to the restorative position could not be established with great accuracy, even with a simulated abutment projection. However, new and innovative tools have been incorporated into the software that can facilitate the process. The author has postulated that a Triangle of Bone (TOB) can be established over the cross-sectional image to aid in the planning process by visualizing a zone that defines the available volume of bone for implant placement. Using interactive planning tools, a realistic implant can be placed within the TOB, which can help ascertain implant length and width. A realistic abutment placed within the schematic cross-sectional view allows the clinician to plan from within a library of virtual components (supplied by individual implant manufacturers), including most implants currently available with their stocked straight, angled, overdenture, and screw-receiving abutments (Figure 2b).

The CT scan data from the i-CAT CBCT machine was then reconstructed within SimPlant to create a virtual 3-dimensional model of the patient's maxilla (Figure 3a). The ability to visualize the patient's anatomy in 3 dimensions can become exponentially enhanced with proper interactive manipulation. Translucency provides an invaluable diagnostic aid when the outer bone can be made semitransparent to reveal the underlying surrounding tooth roots (Figure 3b). The use of advanced masking allows for specific anatomical structures to be separated, and even colorized, thereby intensifying diagnostic capabilities. The occlusal view of the maxilla showing the edentulous receptor site and maxillary teeth, colored individually and in groups, can be seen in (Figure 4). The improved features of the software have made it easier to remove the bone entirely to gain access to anatomy, which had been previously hidden from view. Accurate placement of another virtual realistic tapered implant (Tapered Internal Implant [BioHorizons]) from the manufacturers' library was facilitated with these advanced modalities (Figure 5a). The coronal position of the implant, as well as the apical position of the implant, can be evaluated easily with respect to the adjacent tooth roots and area that was suspect in the original periapical radiograph. The abutment projection (in yellow) is helpful in identifying the overall spatial position of the implant as it points toward the envelope of the proposed tooth.

The goal is the tooth that we replace, and therefore the development of the virtual tooth is an important evolutionary step for virtual implant planning. The 3-D maxilla, with the virtual lateral incisor tooth (in yellow) can be seen in Figure 5b. The virtual tooth can be scaled to fit the space and allow inspection of the contact areas, the distance to the crest of the alveolar bone, and the aesthetics. Removing the bone and adding translucency helps to finalize the position of the implant and abutment (Figure 5c). The 3-D model can be rotated in any position, allowing for ultimate inspection and appreciation of the site. The body and thread design of the implant can be fully visualized. The assessment of apical proximity to the adjacent tooth roots is especially useful when planning implants near natural teeth. The occlusal view affords additional examination of the relationship of the implant, the abutment,

continued on page 126

Restoratively Driven Implant...

continued from page 124

and the virtual tooth to the surrounding structures (Figure 6a). When the adjacent teeth, the virtual tooth, and the abutment are removed, the implant receptor site can be compared to the morphology of the neighboring alveolar housings (Figure 6b). This type of assessment represents how these 3-D tools can be used to define new paradigms for implant planning, and serves as an excellent educational opportunity for all members of the implant team.

Once the plan has been reviewed in all available views, and the implant position finalized, the information can be shared with the patient, and if applicable, members of the implant team. The widespread use of computers and high-speed Internet access allow for quick and easy exchange of this important information, within the constraints of HIPAA. The incorporation of this technology into daily practice goes well beyond excellent diagnostic capability and empowers clinicians with a powerful communication and marketing tool. With a desktop or laptop computer, the images can be easily incorporated into an impressive presentation, helping patients understand the treatment recommendation. Once a patient accepts the treatment plan, the data is sent via e-mail for fabrication of a CT-derived template to link the virtual plan to the surgical intervention (SurgiGuide [Materialise Dental]). The template can be bone-borne, tooth-borne, or soft-tissue-borne, depending upon the software application utilized. For this case, a tooth-borne template was necessitated by the partially edentulous condition.

A stereolithographic process fabricates the tooth-borne template. The 5.0-mm-tall stainless steel cylinder supplies surgical guidance that can be of variable diameter based upon the drills to be used to create the osteotomy (Figure 7a). Three different templates are used for the SurgiGuides, which represent the 3 different manufacturer-specific drills for sequential osteotomy preparation. A 3.75-mm-diameter x 13-mm-long implant (Tapered Screw-Vent [Zimmer Dental]) was chosen and placed according to the CT plan (Figure 7b). Since the bone density and topography had been previously assessed from the CT data and, knowing the excellent fixation properties of the implant, it was determined that the implant could be immediately restored. Based upon the use of the advanced planning features of the interactive software, the implant was rotated so that the flat of the internal hex connection was facing toward the buccal. A precontoured stock abutment, ready at the time of surgery, was placed for immediate temporization (Figure 7c). The ability to assess the restorative requirements of the receptor site has been greatly enhanced with the development of the "virtual tooth" and the realistic abutment that can be positioned within the envelope of the desired tooth position. The position of the real abutment intraorally matched the virtual plan, revealing an adequate distance between the pre-machined margins of the abutment and the adjacent teeth. This is important for papilla preservation (Figure 8). As the apex of the maxillary right central incisor root is in close proximity to the implant, it was advisable to place the implant with the aid of a CT-derived template.

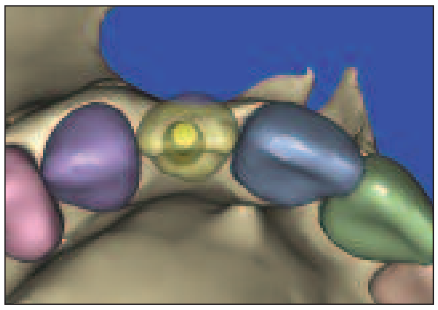

Figure 6a. The occlusal view affords additional examination of the relationship of the implant, the abutment, and the virtual tooth.

Figure 6b. The adjacent teeth, virtual tooth, and the abutment were removed so that the implant position can be compared to the morphology of the neighboring alveolar housings.

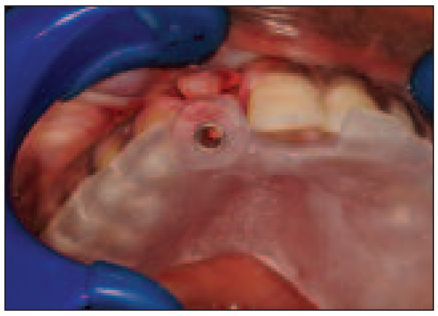

Figure 7a. The stereolithographic tooth-borne template contains a 5.0-mm-tall stainless steel cylinder for surgical drill guidance.

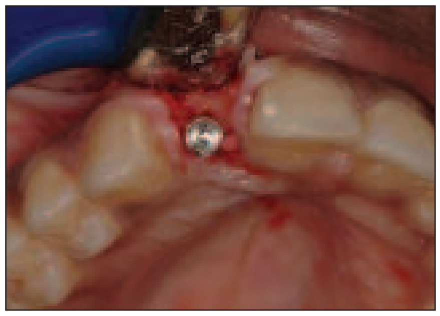

Figure 7b. A 3.75-mm-diameter x 13-mm-long implant was placed according to the CT scan plan.

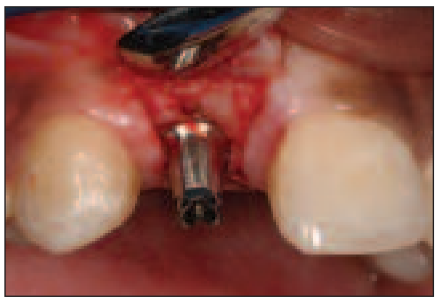

Figure 7c. A precontoured stock abutment, ready at the time of surgery, was placed on the implant for immediate temporization.

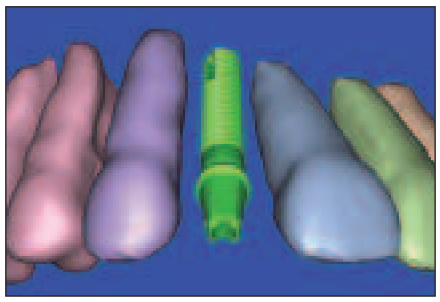

Figure 8. The position of the real abutment intraorally matched the virtual plan.

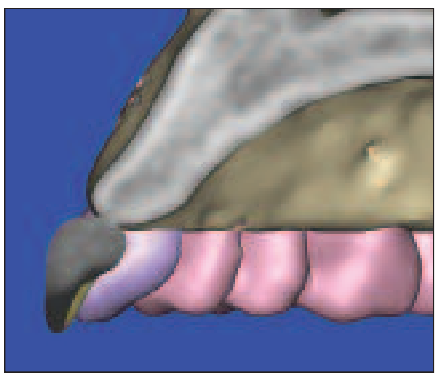

Figure 9a. A slice through the 3-D model and the virtual tooth provides clinicians with previously hidden information about the implant receptor site.

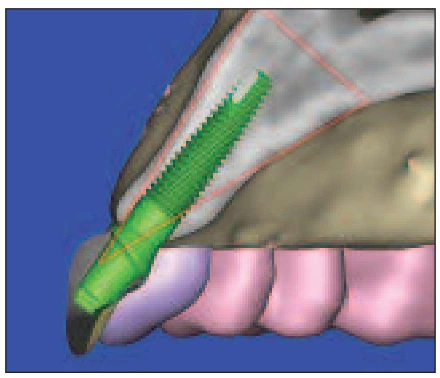

Figure 9b. The buccal and palatal cortical thickness surrounding the dense trabecular bone was evaluated to properly position the implant within the zone of the TOB.

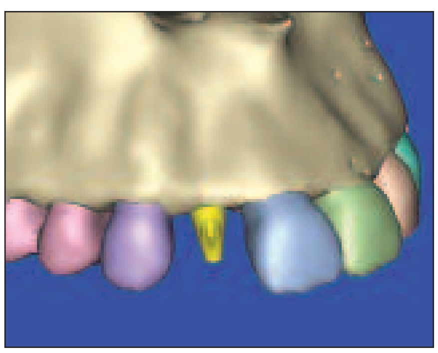

Figure 10a. A virtual, realistically angulated abutment for a cementable restoration is shown.

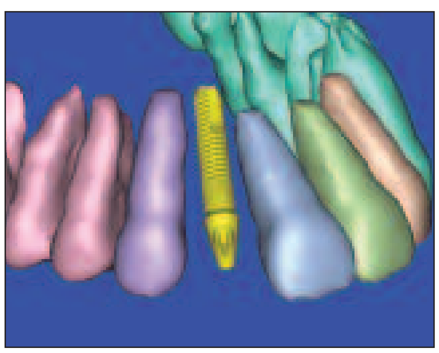

Figure 10b. Removing the bone reveals a virtual, realistic, straight-walled implant.

Additional information can be obtained by slicing through the 3-D model, with the virtual tooth. This highly diagnostic view provides clinicians with previously hidden information about the implant receptor site (Figure 9a). While it may be difficult for clinicians unfamiliar with standard CT images to interpret the information, the 3-D images are easily understood. The buccal and palatal cortical thickness surrounding the dense trabecular bone can be evaluated so that the implant can be properly positioned within the zone of the TOB (Figure 9b). Note that the realistic abutment has been rotated so that the lower premachined margin has been placed toward the facial, and the higher margin toward the palate. The virtual implant library can aid clinicians in planning cases with a variety of different implants and prosthetic components. A virtual, realistically angulated abutment for a cementable restoration can be seen in Figure 10a. Removing the bone reveals a virtual, realistic, straight-walled implant (OsseoSpeed [Astra Tech]), which was placed to avoid close proximity to the adjacent roots (Figure 10b). Therefore, this technology can be utilized for most available implant systems currently available and presently incorporated into the software for planning and template fabrication.

CONCLUSION

In the past, 2-D imaging was inherently limiting. For single-tooth applications especially, clinicians do not feel the need for 3-D volumetric imaging for diagnosis of available bone. However, the acceptance of CT and CBCT has

The ability to virtually plan the case, discuss the case with members of the implant team, present the case to the patient, and execute the plan with a high degree of accuracy through the use of surgical templates has, in the author's opinion, elevated the art of implant dentistry into the science of implant dentistry.

helped clinicians expand beyond their conventional imaging modalities to understanding the 3-D anatomical presentations of their patients and the importance of this technology, even for missing single teeth. This article dealt with a patient who came to the consultation appointment with her CT scan data on a disk and exemplifies that patients are also becoming more knowledgeable about this important technology.

Interactive treatment planning software can take the CBCT data and reprocess it in a manner that can be readily utilized for evaluating potential implant receptor sites. The continued development of software applications to incorporate realistic virtual implants, realistic abutments, and virtual teeth takes the technology to new levels of accuracy, allowing for true, restoratively driven implant dentistry. This type of assessment represents how these 3-D tools can be used to define new paradigms for implant planning, and serves as an excellent educational opportunity for all members of the implant team. Simulating the placement of implants must then be transferred to the patient utilizing a CT-derived template, which aids in surgical accuracy and avoidance of vital anatomical structures.

The ability to virtually plan the case, discuss the case with members of the implant team, present the case to the patient, and execute the plan with a high degree of accuracy through the use of surgical templates has, in the author's opinion, elevated the art of implant dentistry into the science of implant dentistry. Although available since the early 1990s, it has been only recently that clinicians worldwide have started to utilize this technology to define new paradigms in understanding anatomy and implant planning. Even the dental implant companies have recognized the importance of this modality for proper diagnosis and treatment planning as evidenced by new software and hardware product offerings. As the author states, "There is a danger when we are bound by 2-D concepts when we live in a 3-D world." The evolution will continue!✦

Suggested Readings

Farr C. Computer-assisted implant planning and presentation. *Dent Today.* June 1995;14:38-41.

Ganz SD. The triangle of bone – a formula for successful implant placement and restoration. *Implant Soc.* 1995;5:2-6.

Ganz SD. Presurgical planning with CT-derived fabrication of surgical guides. *J Oral Maxillofac Surg.* 2005;63(suppl 2):59-71.

Ganz SD. Conventional CT and cone beam CT for improved dental diagnostics and implant planning. *Dent Implantol Update.* 2005;16:89-95.

Ganz SD. The reality of anatomy and the triangle of bone. *Inside Dentistry.* June 2006:72-77.

Ganz SD. The next logical progression – realistic abutments. Materialise Web site, News/Press releases. http://www.materialise.com/materialise/view/en/662046-Realistic+Abutments.html. Published April 20, 2007. Accessed May 27, 2008.

Ganz SD. CT-derived model-based surgery for immediate loading of maxillary anterior implants. *Pract Proced Aesthet Dent.* 2007;19:311-318.

Kan JY, Rungcharassaeng K. Immediate placement and provisionalization of maxillary anterior single implants: a surgical and prosthodontic rationale. *Pract Periodontics Aesthet Dent.* 2000;12:817-824.

Kois JC. Predictable single-tooth peri-implant esthetics: five diagnostic keys. *Compend Contin Educ Dent.* 2004;25:895-900.

Nevins M, Camelo M, De Paoli S, et al. A study of the fate of the buccal wall of extraction sockets of teeth with prominent roots. *Int J Periodontics Restorative Dent.* 2006;26:19-29.

Peñarrocha M, Lamas J, Peñarrocha M, et al. Immediate maxillary lateral incisor implants with nonocclusal loading provisional crowns. *J Prosthodont.* 2008;17:55-59.

Richardson G, Russell KA. Congenitally missing maxillary lateral incisors and orthodontic treatment considerations for the single-tooth implant. *J Can Dent Assoc.* 2001;67:25-28.

Rosenfeld AL, Mandelaris GA, Tardieu PB. Prosthetically directed implant placement using computer software to ensure precise placement and predictable prosthetic outcomes. Part 1: diagnostics, imaging, and collaborative accountability. *Int J Periodontics Restorative Dent.* 2006;26:215-221.

Salama H, Salama MA, Garber D, et al. The interproximal height of bone: a guidepost to predictable aesthetic strategies and soft tissue contours in anterior tooth replacement. Pract Periodontics Aesthet Dent. 1998;10:1131-1141.

Sarment DP, Al-Shammari K, Kazor CE. Stereolithographic surgical templates for placement of dental implants in complex cases. *Int J Periodontics Restorative Dent.* 2003;23:287-295.

Tarnow DP, Magner AW, Fletcher P. The effect of the distance from the contact point to the crest of bone on the presence or absence of the interproximal dental papilla. *J Periodontol.* 1992;63:995-996.

Dr. Ganz is a graduate from the University of Medicine and Dentistry of New Jersey Dental School. He completed a 3-year specialty program in maxillofacial prosthetics at MD Anderson Cancer Center in Houston, Tex. He has delivered presentations internationally on the prosthetic and surgical phases of implant dentistry. Dr. Ganz is considered one of the world's leading experts in the field of computer utilization for diagnostic, graphical, and treatment planning applications in dentistry. He has been published in various scientific and professional journals. Dr. Ganz's book, *An Illustrated Guide to Understanding Dental Implants* (available in English and Spanish), has received wide acclaim as the standard in patient education texts. He is on the implant faculty of many preceptorship programs nationally, is on the staff of Hackensack University Medical Center, past faculty of the University of Pennsylvania Dental School, and currently on faculty at UMDNJ Dental School. He has served as a consultant for numerous companies for the past 15 years. Dr. Ganz is a past president of the NJ Section of the American College of Prosthodontists and maintains a private practice for prosthodontics, maxillofacial prosthetics, and implant dentistry in New Jersey. He also developed and maintains an Internet FORUM on interactive CT scanning technology, and was a founding member of the Simplant Academy, headquartered in Lueven, Belgium (simplantacademy.org). He can be reached at (201) 592-8888 or sdgimplant@aol.com.